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The joint contribution of physical activity, insomnia symptoms and smoking to the cost of short-term sickness absence

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Running head: Health behaviour and sickness absence cost

Key words: longitudinal study, absenteeism, lifestyle, sedentary behaviour, sleep, tobacco use

ABSTRACT

Physical inactivity has been associated with both insomnia symptoms and smoking. Further, they are all independently associated with increased sickness absence (SA) from work. However, joint contribution of either physical activity (PA) with insomnia symptoms or with smoking to SA and, especially, their direct cost for the employer, are poorly understood. Therefore, we aimed to examine these joint associations with short-term (<15 days) SA cost. The Helsinki Health Study is a cohort of midlife employees of the City of Helsinki, Finland (baseline n=8960, response rate 67%). During 2000-2002 the participants were mailed a survey questionnaire that gathered information on health behaviour and sociodemographic characteristics. SA, salary, and time of employment were followed up through the employer's personnel register between 2002-2016 for those with a written consent to the use of their register data (78% of the participants). Individual salary data were used to calculate the direct cost of short-term SA. Data were analysed with a two-part model. Inactive participants with frequent insomnia symptoms had 2526€ (95% CI 1736€-3915€) higher cost of short-term SA than vigorously active participants without insomnia symptoms. Furthermore, inactive smokers had 4166€ (95% CI 2737€-5595€) higher cost for the employer over the follow-up than vigorously active non-smokers. In conclusion, this study showed that PA and insomnia symptoms as well as PA and smoking are jointly associated with short-term SA cost. The results emphasize encouraging employers to improve work environments so that they promote active lifestyle, good sleep and non-smoking in order to reduce the cost of SA.

INTRODUCTION

Physical inactivity increases the risk of various chronic diseases. These result in high medical and economic burden for societies.[1] Besides its contribution to healthcare cost, physical inactivity increases sickness absence and productivity loss,[2–4] generating considerable cost for the employers.[5] Even though studies have established individual association of physical activity with sickness absence and their cost, physical activity may also contribute to sickness absence through interacting with other risk factors. Such joint associations are poorly understood.

Along physical activity especially smoking [2,6] and insomnia symptoms [7,8] are strongly related to increased sickness absence and their cost.[9] Both smoking and insomnia symptoms have also been linked to physical activity. Our earlier prospective study implies that the association between physical activity and insomnia symptoms may be bidirectional.[10] Thus, insomnia may induce inactivity, but results from both observational [11–13] and intervention studies [14–17] suggest that physical activity improves sleep quality and reduce insomnia symptoms in different populations. Therefore, it could be hypothesized that higher physical activity may improve sleep quality which would together lead to higher work productivity, decreased sickness absence and their subsequent cost.

Association between physical activity and smoking may also be bidirectional. Daily smoking has been found to increase the likelihood of remaining or becoming physically inactive over the decades.[18,19] In contrast, studies on mortality have found out that while smoking during midlife primarily increases the risk of death, physical inactivity appears to counteract the survival benefits of smoking cessation.[20] Our earlier study showed that vigorous activity might help prevent disability retirement among never and ex-smokers and moderate smokers, but among heavy smokers, physical activity is not sufficient to eliminate the adverse effects of smoking.[21]

In the current study, we aimed to explore the joint contribution of physical inactivity and frequent insomnia symptoms as well as physical inactivity and smoking to the cost of short-term (<15 days) sickness absence for the employer. Based on earlier studies on these risk factors, we expected that the cost of sickness absence that is attributable to simultaneous physical inactivity and frequent insomnia symptoms or simultaneous physical inactivity and smoking is even higher than their independent contributions. The paper presents results with over 10 years of follow-up among midlife employees of the City of Helsinki, Finland, using individual sickness absence and salary data obtained from the employer's comprehensive personnel register.

MATERIALS AND METHODS

Participants

Helsinki Health Study invited employees of the City of Helsinki (N=13344) to participate in the mail questionnaire survey in 2000-2002.[22] At baseline, the cohort comprised 8960 (response rate 67%) employees aged 40, 45, 50, 55, and 60 years. The participants were followed-up through the employer's comprehensive personnel register on sickness absence, salary, and time of employment. Register linkage was done, using unique personal identification numbers given to each Finnish citizen. Those who did not give their consent for register linkage (n=1974, 22%) were excluded from this study. Of the remaining participants, those who were not working during the follow-up (n=471) or had either salary, working time or both missing in the first follow-up year (n=71) were excluded. Final analysis sample comprised of 6444 participants (80% women, representing gender distribution in the public sector in Finland).

Ethics committees of the Department of Public Health, University of Helsinki, and the City of Helsinki health authorities, Finland, have approved the Helsinki Health Study protocol.

Main outcome: direct cost of short-term sickness absence for the employer

The short-term sickness absence (<15 days) of the participants were followed up using the employer's register (maintained by the City of Helsinki). The follow-up was considered to begin January 1st, 2002, and continued until the end of 2016, or until the end of the employment contract. Furthermore, if the participant had either salary, working time or both missing in some follow-up year, the participant was followed up until the last year when all information was available. Individual annual gross salary data were used to calculate the cost of short-term sickness absence for each individual and follow-up year by multiplying the total annual number of short-term sickness absence days with the daily salary of the specific year. Then the figures for each follow-up year were summed to give the total cost of short-term sickness absence in euros over the 10 years follow-up, which was used as the main outcome in the analyses. More details are available elsewhere.[9]

Main exposures: Physical activity, insomnia symptoms and smoking

The average weekly hours of physical activity during leisure time or commuting within the previous 12 months was estimated with a question that had 4 grades of intensity: walking, brisk walking, jogging, and running or their equivalent activities.[3] Each intensity grade was divided into 5 response alternatives from 0 hours to 4 hours or more. Metabolic equivalents

(MET) were used to approximate the amount of physical activity. MET hours per week were calculated by multiplying the time spent in physical activity with the MET value of each intensity grade and adding the 4 values together. Participants with weekly exercise <14 MET hours per week were classified as physically inactive. Furthermore, those with ≥14 MET hours per week on the two lowest intensity grades as moderately active, and ≥14 MET hours per week including exercise at the two highest intensity grades as vigorously active.[5]

Insomnia symptoms were measured by four items asking difficulties initiating and maintaining sleep ("How often in the past month did you: 1) have trouble falling asleep 2) wake up several times per night? 3) Have trouble staying asleep?") as well as non-restorative sleep ("How often in the past month did you: 4) wake up after your usual amount of sleep feeling tired and worn out?") during the previous month.[23] Six response alternatives ranged from "never" to "in 22-28 nights per month". Insomnia symptoms were categorized to those who reported insomnia symptoms <4 nights per month; those who reported having any of the insomnia symptoms 4-14 nights per month; and those reporting any of the insomnia symptoms >14 nights per month.

In the baseline questionnaire, participants were asked whether they currently smoked regularly. Those who answered "yes" were classified as current smokers. Those who reported former regular smoking habit were classified as former smokers, and those who responded negatively to both of these questions were classified as non-smokers.

The joint variables for physical activity and insomnia symptoms as well as physical activity and smoking were formed using vigorously active - no insomnia symptoms, and vigorously active - non-smokers as reference categories. The categories and their distributions are displayed in supplementary table 1.

Confounders and intermediaries

The baseline questionnaire gathered information on participants' sociodemographic (age, sex, marital status) and health characteristics (physical functioning, and body mass index, BMI). Occupational class was obtained through the employer's personnel register and categorized as follows: managers or professionals, semi-professionals, routine non-manuals, or manual workers. In the questionnaire, participants were asked to report their current marital status using the following categories: married, co-habiting, single, widowed, or divorced/separated. Physical functioning was assessed, using the Short Form 36 Health Survey's subscale for physical functioning.[24] The score ranges from 0 to 100, higher scores representing better physical functioning. BMI was calculated as weight (kg) divided by the square of height (m^2), based on participants' self-reported weight and height. Consumption of different alcohol types (beer/cider/wine/spirits) was reported on 7 frequency categories. The consumption of various food items was measured with a 22-item food frequency questionnaire that was included in the baseline questionnaire.[25] From the food frequency questionnaire, fresh fruit and vegetable consumption was selected as a marker of healthy eating and categorized to non-daily fruit and vegetable consumption (<1 times/day), daily consumption of either fruits or vegetables, and daily consumption of both fruits and vegetables.

Statistical analyses

The analyses were performed, using R statistical software version 3.3.2,[26] and STATA version 12 (Stata Corp, College Station, TX, USA). Since no sex interaction was found (p=0.27 for insomnia symptoms – physical activity; p=0.76 for smoking – physical activity) the analyses were conducted pooling men and women. Differences in lifestyle factors (physical activity, sleep, smoking, alcohol use, and fruit and vegetable consumption) by consenters and non-consenters were tested, using χ^2 test.

In total, 788 participants had missing information in physical activity, smoking, and insomnia symptoms, and 197 participants had missing information in the background variables. Missing information in these independent variables was imputed, using predictive mean matching (‘mice’ procedure in package mice in R) which is a powerful and statistically valid method for creating imputations in large data sets including both categorical and continuous variables.[27] All analyses and tables are presented for the imputed dataset (n=6444), unless otherwise mentioned.

Association between the joint variables and cost of short-term sickness absence for the employer were analysed, using a two-part model. The two-part model was used as individual-level data on cost of sickness absence typically feature a spike at zero and a strongly skewed distribution with a heavy right-hand tail. Ignoring the large number of zeros can have two consequences; firstly, the estimated parameters and standard errors may be biased, and secondly, the excessive number of zeros can cause overdispersion. The two-part model distinguishes between a binary indicator, used to model the probability of any cost, and a conditional regression model for the positive cost. Thus, first the association between joint variables and the probability of having cost of short-term sickness absence was analysed among all participants, using logistic regression with binomial distribution. Then, a generalised linear model with gamma distribution and log-link function was used to analyse association between the joint variables and cost of short-term sickness absence among participants who had cost during the follow-up.

To control for confounding, all analyses were first adjusted for age (continuous: years), sex (categorical: men / women) and follow-up time (continuous: years). The second model was additionally adjusted for marital status (categorical: married, co-habiting, single, widowed, or divorced/separated) and occupational class (categorical: managers or professionals, semi-professionals, routine non-manuals, or manual workers); third model for physical functioning (continuous; SF-36 subscale points); the fourth model for BMI (continuous: kg/m^2); and fifth for alcohol (continuous: portions of different alcohol types) and fruit and vegetable consumption (categorical: both daily, either daily, neither daily), and for insomnia symptoms (categorical: no symptoms, occasional symptoms or frequent symptoms) or smoking (non-smoker, former smoker, current smoker) depending on which one was included in the joint variable.

Based on the two-part model, marginal effects were evaluated at covariate means to provide estimated effect of the joint variables on employer's cost in monetary terms ('tpm' and 'margins' procedure in STATA). Testing of interaction was done by first running a model without an interaction term between the main exposures (physical activity and insomnia symptoms or physical activity and smoking), and then a model that included the interaction term. Likelihood ratio test was used to test whether adding the interaction term improved the model statistically significantly. Finally, as a sensitivity test, we also conducted complete-case analyses (n=5459).

RESULTS

Mean follow-up time was 9.8 years (95% CI 9.7-10.0) (table 1). Furthermore, 82.9% of the participants were followed-up through the registers longer than 4 years, and 92.8% were followed longer than 2 years. On average, an employee was absent on a short-term sick leave for 62.5 days over the 10-year follow-up (6 absence days per year), with an average cost of 9057€ per 10 years follow-up for the employer (table 1). Women had more cost from short-term sickness absence leaves compared to men. Differences in lifestyle factors by consenters and non-consenters are shown in supplementary table 2.

Results from the two-part model are presented in the supplementary table 3. Monetary estimates (€ / 10 years follow-up) for the joint contribution of physical activity – insomnia symptoms and physical activity – smoking on employer's direct cost of short-term sickness absence that are based on the two-part model are shown in table 2, and in figure 1 and 2. For physical activity and insomnia symptoms, those who were vigorously active and had no insomnia symptoms formed the reference group. Physical inactivity (inactive - no insomnia symptoms) was associated independently with higher sickness absence cost (table 2). Further, both occasional (vigorously active - occasional insomnia symptoms) and frequent insomnia symptoms (vigorously active - frequent insomnia symptoms) were associated independently with the cost. Of the joint associations, moderately active or inactive participants with frequent insomnia symptoms had the highest cost. These groups had 2825€ (95% CI 1736€ to 3915€) and 2526€ (95% CI 1237€ to 3815€)) higher cost from short-term sickness absence for the employer over the follow-up compared to the reference group (figure 1). Monetary estimates for the joint associations where somewhat higher compared to the independent estimates of physical activity and insomnia symptoms (table 2, figure 1). Statistically significant interaction was found between physical activity and insomnia symptoms in the cost of short-term sickness absence when the model was adjusted for age, sex, follow-up time, marital status and occupational class (likelihood ratio test p=0.011, table 2).

For physical activity and smoking, those who were vigorously active and did not smoke formed the reference group. Both moderate (moderately active – non-smoker) and low physical activity (inactive – non-smoker) associated with higher cost of short-term sickness absence (table 2). Current smoking (vigorously active – smoker) also associated independently with higher cost. Of the joint associations, inactive smokers had 4166€ (95% CI 2737€ to 5595€) higher cost of short-term sickness absence for the employer over the 10-year follow-up compared to vigorously active non-smokers (figure 2). The joint cost was indicative of additive interaction, but no statistically significant interaction between physical activity and smoking was observed (likelihood ratio test p=0.52; table 2).

All results attenuated but remained statistically significant after adjusting for marital status, occupational class and follow-up time. Furthermore, additional adjustments for physical functioning, BMI, alcohol, and other health behaviour (alcohol and fruit and vegetable consumption, and insomnia symptoms or smoking depending on which one was included in the joint variable) attenuated the estimates but neither removed statistical significance nor changed the interpretation of the results (supplementary table 4). In sensitivity testing, all analyses were re-done as complete-case analysis (n=5459). The results between complete-case analyses and imputed analyses were generally similar (supplementary table 5).

DISCUSSION

We examined the joint contribution of physical activity and insomnia symptoms as well as physical activity and smoking to short-term sickness absence cost over a follow-up of 10 years. The simultaneous inactivity and frequent insomnia symptoms, as well as inactivity and smoking seemed to increase the cost, but evidence of interaction was found only for joint association of physical activity and insomnia symptoms. Those who were moderately active or inactive and had frequent insomnia symptoms had the highest cost compared to those who were vigorously active and had no insomnia symptoms. Similarly, inactive smokers had the highest cost of short-term sickness absence compared to vigorously active non-smokers.

Modifiable risk factors may triple sickness absence cost

There are only few studies that have examined the association of physical activity, insomnia symptoms, or smoking with cost of sickness absence. Furthermore, varying methods of recording absence and absence-related cost, as well as differences in legislation of which payments are covered by the employer makes international comparisons difficult. In previous studies that have focused on defining medical cost [28–30] or on productivity losses,[29,31] physical inactivity, former smoking, and larger BMI have been associated with higher medical cost for the employer. Studies that have measured association between modifiable risk factors (health behaviours or biometric measures) and medical [28,30] or salary [5,9] cost found that a high-risk individual had approximately three times the cost of a risk-free individual, which is about the same magnitude that we observed in the current study.

Most studies on sickness absence are concentrated on longer-term sickness absence (>14 days), probably because these are available through national registers in Nordic countries. However, more attention should be given to short-term sickness absence. Longer term absence which may eventually lead to permanent exit out of paid employment for disability retirement is often preceded by multiple short-term absence.[32] Consequently, findings on how to reduce the short-term sickness absence may also lead to reduction in the longer – and costly – sickness absence as well. In addition, the Social Insurance Institution of Finland compensates the salary cost for sickness absence spells that last over 14 days to the employer. The amount of compensation depends on the type of employment and profession, which hampers the estimation of true direct salary costs.

Methodological considerations

The strengths of our study are the prospective design with a long follow-up time. A large majority of our study population was females, which reflects the gender division in our target population, the City of Helsinki, and Finnish public-sector employees in general. Thus, results may not be directly generalizable to the private sector.

Using the individual salary and sickness absence day data from the employer's comprehensive personnel register allowed us to more accurately estimate the direct costs of short-term sickness absence compared to self-reported sickness absence days and average salary data. Individual-level salary information is recommendable as salary level of employees may systematically differ between the risk factors. It should be noted that the gross salary figures used in the study do not include employer's social security costs and pension insurance premium. Furthermore, the salary costs of short-term sickness absence do not represent the total financial costs of physical activity and insomnia symptoms or physical activity and smoking for the employer. To give a complete estimate of the productivity loss the estimation should consider also other direct and indirect costs, such as presenteeism, delays in production and delivery and cancellations due to absenteeism, as well as need to hire a substitute to cover the one who is absent (depending on profession).

Using the baseline physical activity, insomnia symptoms and smoking as predictors of the short-term sickness absences is a potential limitation of the study as participants may have changed their behaviour right before or during the follow-up. Generally, smoking in Helsinki area has been decreasing for decades in men and also since the late 1990's in women.[33] However, prevalence is still relatively high among the working-aged people, although somewhat lower as compared to many OECD countries.[34] Current trends further suggest that the proportion of those who are physically inactive has declined steadily.[35] More specifically in our cohort, physical activity increased among those in the higher classes and decreased among manual workers.[36] In contrast to the positive trends in smoking and physical activity, insomnia symptoms continue to increase particularly in the working-age population.[37] Overall, taking account the changes in physical activity, insomnia symptoms and smoking, our results may include some over- and underestimation (depending on the exposure) of the cost over the whole follow-up period.

Another limitation of our study is that physical activity, insomnia symptoms and smoking were based on questionnaire data and not on measurements. The reliance upon self-report may have resulted in misclassification of employees. Finally, physically inactive people and current smokers were likely overrepresented among the non-respondents (supplementary table 2). This likely makes our results conservative. The physical activity questionnaire has not been validated yet, but a similar questionnaire used by the Finnish Twin Cohort in earlier phases of their study has proven valid against a detailed interview.[38] In addition, van Poppel et al.[39] has shown in their review that no questionnaire is superior to others.

We based the selection of confounding variables on preliminary information on the association between the confounders, the risk factors and sickness absence. Even though adjusting for sociodemographic and health characteristics led to attenuation of the results, the interpretation of the results was unaffected. Admittedly, it is also possible that variance in, for example, marital status and occupational class between joint variable categories was so small in our cohort that it did not allow us to detect their effect on the main results. Furthermore, some of the background variables are also sensitive to misreporting and changes during follow-up. Thus, like all observational epidemiological studies, we cannot rule out the possibility that the effect sizes in our study may be affected by residual or unmeasured confounding.

Concluding remarks

In our study, inactive participants who have frequent insomnia symptoms and inactive participants who smoke had the highest cost of short-term sickness absence. However, statistically significant joint association was observed only between physical activity and insomnia symptoms when examining their associations with cost of short-term sickness absence. Our results emphasize encouraging employers to improve work environment so that it promotes active lifestyle, healthy sleep and non-smoking, which facilitate good work ability and help to reduce the cost of sickness absence.

PERSPECTIVE

In our cohort, the size of the risk groups of inactive poor sleepers and inactive smokers were 6-7% of the total study population. This may appear as a small proportion, but in a large work place, such as the City of Helsinki comprising 40 000 employees, this would mean 2400-2800 employees who generate 6 000 000€ - 11 000 000€ extra salary cost over 10 years period as on top of the salary that is paid during sick leave, productivity decreases due to the employee's absence. Even though the cost of short-term sickness absence is a notably smaller expenditure to the employers as compared to the total salary cost over 10 year period, it is reasonable to expect that it is, nonetheless, in the employer's interest to prevent such cost. Furthermore, it should be emphasized that our estimates represent only the direct salary costs. Thus, 2000-4000€ cost for the follow-up period is likely to be an underestimate of the total contribution of physical activity and insomnia symptoms as well as physical activity and smoking.

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Figure 1. Marginal effects on cost (mean and 95% CI) of short-term (1-14 days) sickness absence on employer over 10-years' follow-up: joint effect of physical activity (PA) and insomnia symptoms. The analysis was adjusted for age, sex, follow-up time, marital status, and occupational class. Vigorous activity was defined as >14 MET hours per week + strenuous exercise; moderate activity was defined as >14 MET hours per week + no strenuous exercise; and inactivity was defined as <14 MET hours per week.

Figure 2. Marginal effects on cost (mean and 95% CI) of short-term (1-14 days) sickness absence on employer over 10-years' follow-up: joint effect of physical activity (PA) and smoking. The analysis was adjusted for age, sex, follow-up time, marital status, and occupational class. Vigorous activity was defined as >14 MET hours per week + strenuous exercise; moderate activity was defined as >14 MET hours per week + no strenuous exercise; and inactivity was defined as <14 MET hours per week.

Table 1. Distribution, and mean costs of short-term sickness absence by participants' background characteristics.

	Distribution, n	Mean / % (95% CI)	Mean cost of short-term sickness absence, € /10 years (95% CI)
Follow-up time, years	6444	9.8 (9.7-10.0)	
Short-term sickness absence, days/10 years	6444	62.5 (60.7-64.4)	9057 (8767-9346)
Sex			
Men	1199	18.6 (17.7-19.6)	6826 (6330-7322)
Women	5245	81.4 (80.4-82.3)	9567 (9231-9902)
Age, years			
40	1306	20.3 (19.3-21.3)	12451 (11776-13126)
45	1390	21.6 (20.6-22.6)	11678 (11103-12253)
50	1403	21.8 (20.8-22.8)	10704 (10138-11271)
55	1630	25.3 (24.2-26.4)	5822 (5178-6465)
60	715	11.1 (10.4-11.9)	1903 (1686-2120)
Marital status			
Married	3808	12.5 (11.7-13.3)	8208 (7899-8517)
Co-habiting	716	11.1 (10.4-11.9)	10023 (9214-10832)
Single	805	59.1 (57.9-60.3)	11206 (9848-12563)
Widowed	140	15.1 (14.3-16)	7914 (6220-9608)
Separated / Divorced	975	2.2 (1.8-2.6)	10051 (9333-10769)
Occupational class			
Managers and professionals	2062	32 (30.9-33.1)	7730 (7177-8284)
Semi-professionals	1267	19.7 (18.7-20.7)	8813 (8265-9362)
Routine non-manuals	2339	36.3 (35.1-37.5)	10420 (9960-10880)
Manual workers	776	12 (11.3-12.9)	8869 (7943-9795)
BMI, kg/m2			
Underweight <18.5	68	1.1 (0.8-1.3)	9190 (6738-11642)
Normalweight 18.5-24.9	3262	50.6 (49.4-51.8)	8564 (8229-8900)
Overweight 25.0-29.9	2183	33.9 (32.7-35)	8814 (8333-9296)
Obese >29.9 kg/m2	931	14.4 (13.6-15.3)	11341 (10195-12486)
Physical functioning, score points			
Highest fourth (99-100)	1396	21.7 (20.7-22.7)	9590 (877-10402)
Third fourth (95-99)	1279	19.8 (18.9-20.8)	9411 (8839-9982)
Second fourth (85-94)	1255	19.5 (18.5-20.5)	9400 (8711-10088)
Lowest fourth (0-84)	2514	39 (37.8-40.2)	8410 (8030-8790)
Physical activity level			

Vigorous	2159	33.5 (32.4-34.7)	8907 (8474-9341)
Moderate	2739	42.5 (41.3-43.7)	8966 (8577-9355)
Inactive	1546	24 (23-25)	9427 (8642-10212)
Smoking			
Non-smoker	3325	51.6 (50.4-52.8)	7966 (7570-8361)
Former smoker	1581	24.5 (23.5-25.6)	8990 (8482-9499)
Current smoker	1538	23.9 (22.8-24.9)	11484 (10815-12153)
Insomnia symptoms			
<4 nights /month	3071	47.7 (46.4-48.9)	8196 (7827-8566)
4-14 nights/month	2021	31.4 (30.2-32.5)	9896 (9296-10496)
>14 nights/ month	1352	21 (20-22)	9757 (9133-10380)
Drinking			
No consumption	358	5.6 (5-6.1)	7760 (6605-8915)
Moderate consumption	5021	77.9 (76.9-78.9)	8864 (8533-9194)
High consumption	1065	16.5 (15.6-17.5)	10404 (9705-11102)
F&V consumption			
Daily F&V consumer	3045	47.3 (46-48.5)	8426 (8007-8845)
Daily consumer of either F or V	1940	30.1 (29-31.2)	9199 (8671-9727)
Non-daily F&V consumer	1459	22.6 (21.6-23.7)	10184 (9572-10796)

Vigorous activity was defined as >14 MET hours per week + strenuous exercise; moderate activity was defined as >14 MET hours per week + no strenuous exercise; and inactivity was defined as <14 MET hours per week. Moderate alcohol consumption was defined as <8 servings per week for women and <15 servings per week for men. High alcohol consumption was defined as >7 servings per week for women and >14 servings per week for men. F, fruit; V, vegetable.

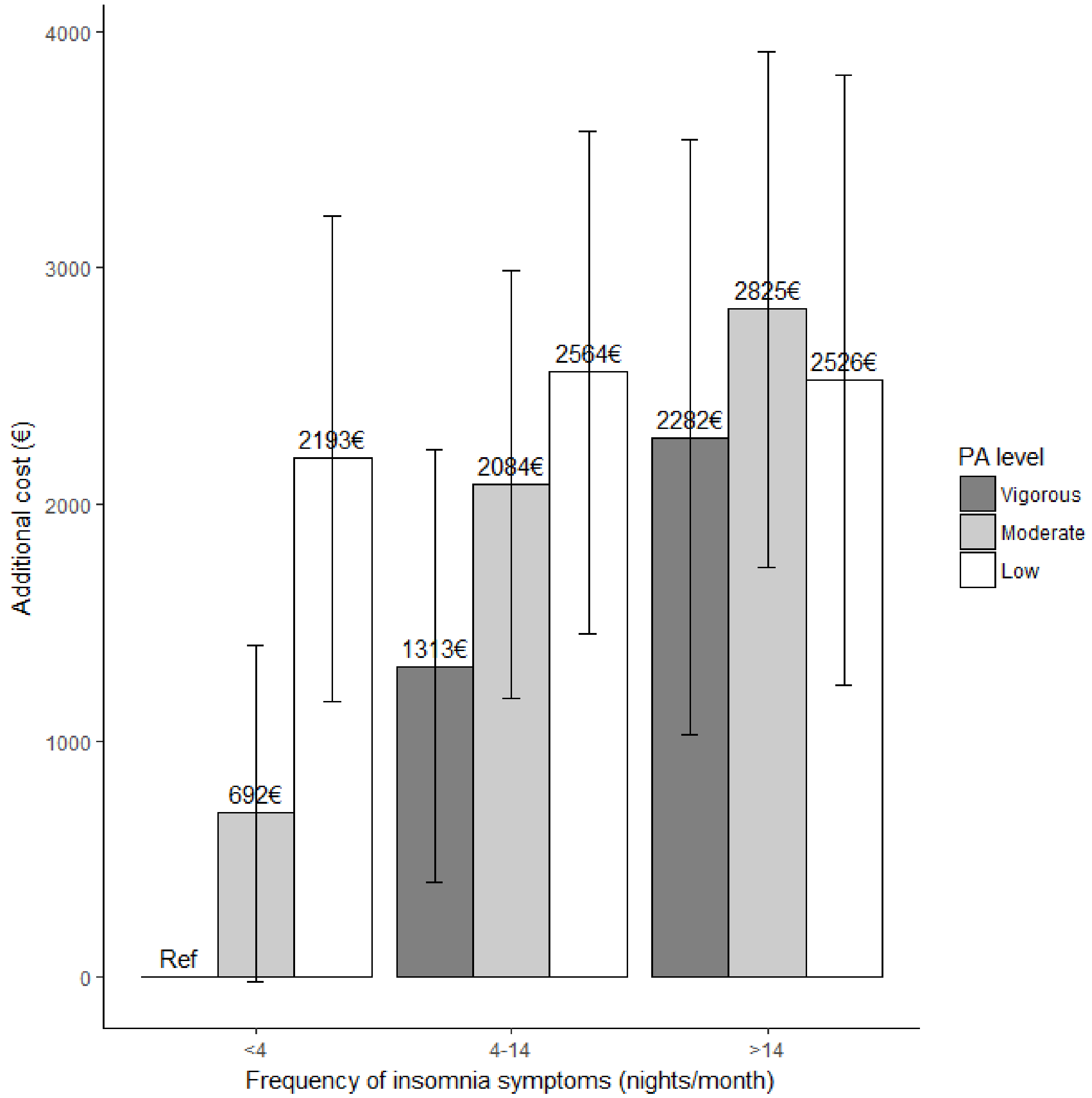
Table 2. Marginal effects on costs (€) of short-term (1-14 days) sickness absence on employer over 10 years: joint effects of physical activity, insomnia symptoms and smoking

	Reference group	Independent association of physical activity		Independent association of insomnia symptoms / smoking		Joint associations			
	Vigorous - no symptoms	Moderate - no symptoms	Low - no symptoms	Vigorous - occasional	Vigorous - frequent	Moderate - occasional	Low-occasional	Moderate - frequent	Low - frequent
Model 1									
dy/dx	ref.	863*	2522***	1191*	2223**	2178***	2645***	3189***	2665***
95% CI		(90-1637)	(1389-3655)	(222-2159)	(880-3566)	(1202-3154)	(1445-3844)	(1987-4392)	(1266-4065)
						Likelihood ratio test for interaction: $p = 0.16$			
Model 2									
dy/dx	ref.	692	2193***	1313**	2282***	2084***	2564***	2825***	2526***
95% CI		(-22-1405)	(1164-3222)	(399-2228)	(1022-3541)	(1181-2988)	(1449-3579)	(1736-3915)	(1237-3815)
						Likelihood ratio test for interaction: $p = 0.011$**			

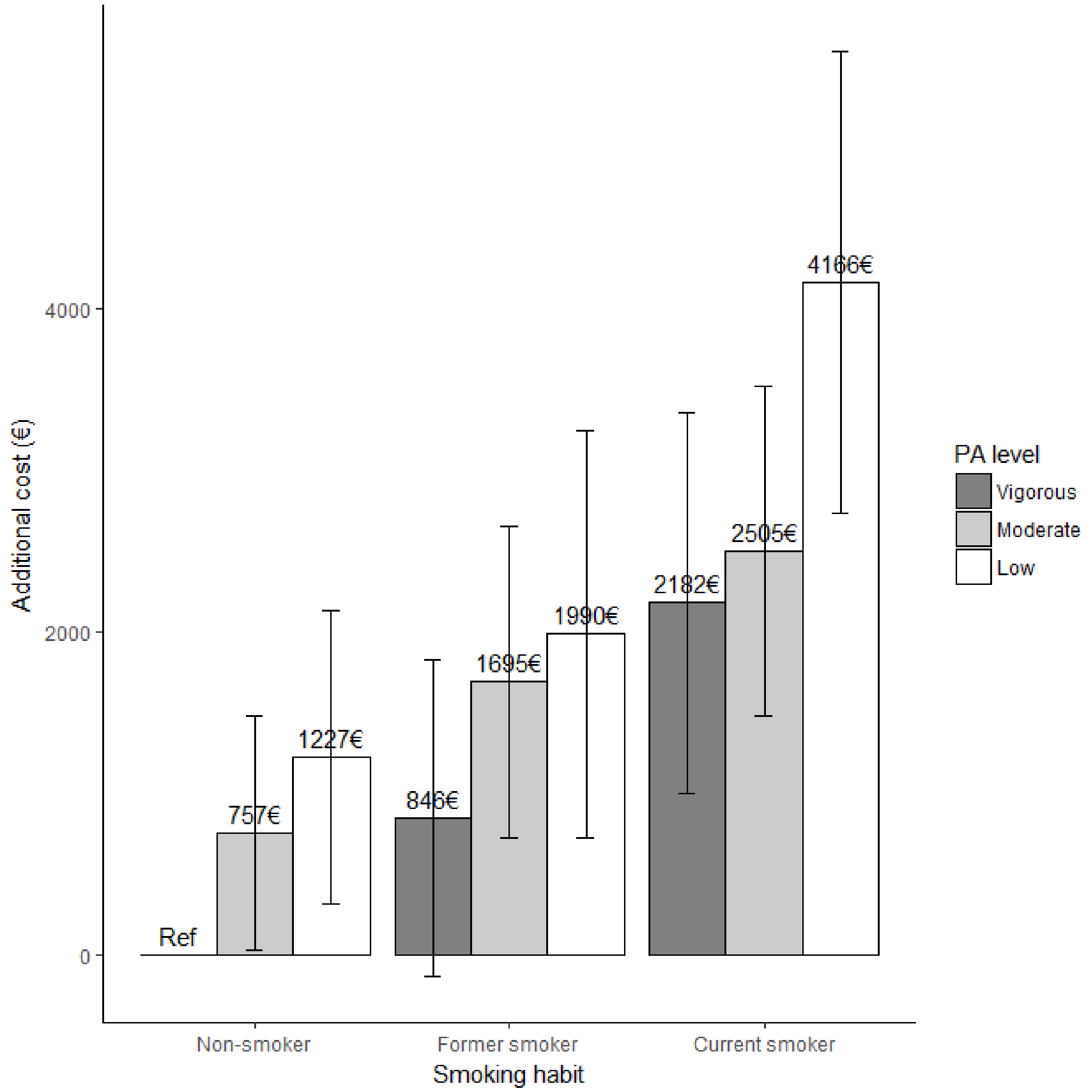
	Vigorous - non-smoker	Moderate - non-smoker	Low - non-smoker	Vigorous - former	Vigorous - current	Moderate - former	Low - former	Moderate - current	Low - current
Model 1									
dy/dx	ref.	902*	1380**	901	2581***	1980***	2176**	3039***	4809***
95% CI		(139-1664)	(419-2342)	(-127-1929)	(1303-3859)	(954-3007)	(833-3519)	(1937-4141)	(3245-6373)
						Likelihood ratio test for interaction: $p = 0.96$			
Model 2									
dy/dx	ref.	757*	1227**	846	2182***	1695**	1990**	2505***	4166***
95% CI		(34-1479)	(318-2135)	(-132-1825)	(1001-3363)	(732-2658)	(731-3248)	(1487-3522)	(2737-5595)
						Likelihood ratio test for interaction: $p = 0.52$			

Marginal effects at covariate means are derived from the two-part model, in which the association between joint variables and probability of having sickness absence costs was first tested among all participants, using binomial model. Then, the association between joint variables and sickness absence cost was analysed among those who had sickness absence cost, using generalized linear model. Model 1 was adjusted for age, sex and follow-up time. Model 2 was adjusted for age, sex, follow-up time, marital status, and occupational class. In physical activity, vigorous activity was defined as >14 MET hours per week + strenuous exercise; moderate activity was defined as >14 MET hours per week + no strenuous exercise; and inactivity was defined as <14 MET hours per week. Insomnia symptoms were measured by four items asking difficulties initiating and maintaining sleep as well as non-restorative sleep during the previous month and categorized as: no insomnia symptoms, <4 nights per month; occasional insomnia symptoms, 4-14 nights per month; frequent insomnia symptoms, >14 nights per month. Testing of interaction was done by first running a model without an interaction term between the main exposures (physical activity and insomnia symptoms or physical activity and smoking), and then a model that included the interaction term. Likelihood ratio test was used to test whether adding the interaction term improved the model statistically significantly.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$



Additional cost (€)
4000
3000
2000
1000
0
Ref
692€
2193€
1313€
2084€
2564€
2282€
2825€
2526€
<4
4-14
>14
Frequency of insomnia symptoms (nights/month)
PA level
Vigorous
Moderate
Low



4000
2000
0
Additional cost (€)
Ref
757€
1227€
846€
1695€
1990€
2182€
2505€
4166€
Non-smoker
Former smoker
Current smoker
Smoking habit
PA level
Vigorous
Moderate
Low